Invermere TSA inventory audit

Revised November 1996

A report was released in August 1994 summarizing results and recommendations arising from an inventory audit conducted during 1993 for the Invermere Timber Supply Area. It has since been noted that an improper field from the inventory database was used for some of the height projections, which affected the volume calculations.

The inventory volume figures have been recalculated as shown in this revised report. The differences are minor, and no changes are necessary to the overall recommendations of the original report. In 1995, a new inventory was carried out in the Invermere Timber Supply Area, and this report also includes results for this new inventory.

Introduction

Background

In British Columbia, forest inventories for specific areas are conducted every 10 to 30 years, with regular updates between re-inventories to reflect changes in the forest due to growth and depletions.

The question "How accurate is the current inventory?" often arises. To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

The Forest Inventory Program refers to this statistical auditing methodology as an Inventory Audit. The objective of the inventory audit is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stand, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since the area sampled constitutes only a portion of the total forested area in the TSA.

The audits provide information that may be useful to the Chief Forester during determinations of the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analyses and allowable annual cut determinations.

This report presents the results of an inventory audit conducted in the Invermere Timber Supply Area (TSA). The Invermere TSA covers an area of just over one million hectares and is located in the eastern portion of the Nelson Forest Region.

The inventory audit was conducted to determine the overall accuracy of the inventory in this TSA. Both the 1974 and the new 1995 inventory are assessed. These audit results are unique to the Invermere TSA and cannot be applied to any other areas in the province.

Methods

Current inventory

The province is divided into 37 TSAs, which can vary from 70 000 hectares to 13 million hectares. Inventories can be performed on a complete TSA or on a portion of it. Inventories are conducted by first delineating forest stands (polygons) on 1:15 000-scale aerial photographs. A number of photo-interpreted variables are assessed for each polygon, including species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using these photo-interpreted variables and empirical yield models.

To keep the estimates current, inventories are regularly updated to account for forest growth and depletions due to harvesting, fire, and the impact of insects and disease damage. Empirical yield models,

such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth; field visits, satellite imagery, and aerial photographs may be used to update for depletions.

The inventory audit for the Invermere TSA was initially based on a random sample of 50 polygons (audit sample) selected from the target population of operable and inoperable forested stands, greater than 61 years of age. The establishment of the audit sample is described below.

For each of the polygons, the existing photo-interpreted variables, updated from the original inventory, were projected to 1993 and fed into the VDYP model to obtain 1993 estimates of the volume per hectare (*inventory volume*). The inventory volume estimates were then compared to volume estimates obtained from the audit sample (*audit volume*).

Audit sample

Forest inventory maps for the Invermere TSA, produced in the 1974 inventory, formed the basis for sampling. A stratified random sample of 50 polygons from lodgepole pine, spruce, balsam, and aspen forest types was selected. This report describes the results obtained from 47 polygons. Three polygons were dropped from the analysis because an unacceptable level of bias was introduced during data collection.

Up to 3 full-measure prism plots and 9 count plots were established within each of the 50 sample polygons. The plots were located systematically, using a triangular design and a randomly selected start point. For large or irregular polygons, only a randomly selected portion of the polygon was sampled. A total of about 150 full-measure and 458 count plots were established. Field data collection and compilation followed the standard Ministry of Forests cruising and cruise compilation procedures. A mismatch of trees within the count and full-measure plots may have introduced bias in terms of the percentage species composition, but it would have minimal effect on the total volume estimates. Utilization limits and merchantability definitions were chosen so that the compiled audit volumes would be comparable to the inventory volumes produced using the VDYP model.

The VDYP model produces net merchantable volumes per hectare, defined as whole-stem volume inside bark of all live trees of dbh 12.5 cm+ to a 10-cm diameter inside-bark top and a 30-cm-high stump, excluding decay as estimated from Ministry of Forests loss factors. Dead potential and veteran trees were not included in the volume estimates.

The cruise compilation routine used by the contractor for the audit sample produced merchantable volume for live and dead potential trees, net of decay, waste, and breakage. An adjustment was made to the compiled volumes to obtain audit volumes that were net of decay only. However, dead potential trees and veterans were not removed from the audit volume.

Once the audit volumes were obtained, they were then compared to the inventory volumes to test the validity of the current inventory.

Revised results of the 1974 inventory

Results of the statistical analysis of the inventory audit for volumes at a 12.5 cm+ dbh utilization level are given in Tables 1 and 2.

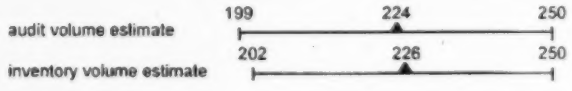
TABLE 1. Statistics for the audit volume and inventory volume estimates at 12.5 cm+ dbh utilization for the Invermere TSA

	Audit Volume Estimate	Inventory Volume Estimate
Number of samples	50	50
Mean (m^3/ha)	224	226
Coefficient of variation (%)	40	37
Standard error (m^3/ha)	12.6	12.0
Sampling error (%)	11.3	10.6
95% confidence interval (m^3/ha)	199–250	202–250

Correlation coefficient $r = 0.297$ (p-value = 0.036)

Ratio of means (audit volume/inventory volume): 0.99

Bar graph representation of 95% confidence intervals (in m^3/ha)



The correlation coefficient of 0.297 for the audit and inventory volume estimates indicates a weak but statistically significant relationship among the individual samples. There is a 2 m^3/ha difference between the mean audit estimate for mature volume (224 m^3/ha) and the mean inventory estimate for mature volume (226 m^3/ha). The sampling error (at the 95% confidence level) was about 11% for both estimates

The ratio of mean audit volume to mean inventory volume was 0.99. A two-sided paired-sample *t-test* showed that there was no significant difference between the estimates of mean volume per hectare for the audit and the inventory.

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (operable areas). The audit results were post-stratified based on this approximation. The results of the inventory audit for samples in the operable forested areas in the TSA are shown in Table 2.

Fifteen of the samples were in inoperable forested areas. Because of the high variability and restrictive nature of conclusions associated with this small sample size, volume estimates from inoperable forested areas are not shown.

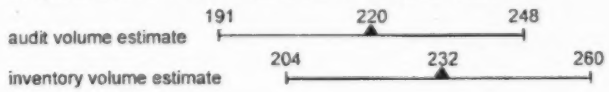
TABLE 2. Statistics for the operable audit volume and inventory volume estimates at 12.5 cm+ dbh utilization for the Invermere TSA

	Audit Volume Estimate	Inventory Volume Estimate
Number of samples	35	35
Mean (m^3/ha)	220	232
Coefficient of variation (%)	38	35
Standard error (m^3/ha)	14.1	13.8
Sampling error (%)	13.0	12.1
95% confidence interval (m^3/ha)	191–248	204–260

Correlation coefficient r = 0.135
(p-value = 0.440; correlation is not significant)

Ratio of means (audit volume/inventory volume): 0.95

Bar graph representation of 95% confidence intervals (in m^3/ha)



For the 35 samples located within operable forested areas, the estimate of mean audit volume was 220 m^3/ha, and the corresponding inventory volume was 232 m^3/ha. The difference between these two estimates was not statistically significant. Sampling errors for the estimates of mean audit volume and inventory volume were 13% and 12% respectively. The correlation coefficient of 0.135 for the operable samples indicates a poor relationship among the individual samples.

Analysis of 1995 inventory

A new inventory was completed in the Invermere TSA in 1995. The original audit samples were re-stratified to correspond to the polygon delineation of this new inventory. After the re-stratification, there were 78 inventory polygons covered by the audit samples, resulting in a varying number of audit sample plots per polygon. Audit volumes were recompiled for all polygons where there was a minimum of one full measure plot. To allow for as close a comparison with the inventory volumes obtained from VDYP as possible, the audit samples were compiled net of decay and excluding dead potential and veteran trees, to a 12.5+ cm dbh utilization.

For the 1995 inventory, the results of the inventory audit for mature volume statistical analyses at the 12.5+ cm dbh utilization limit for the total forested area are given in Table 3.

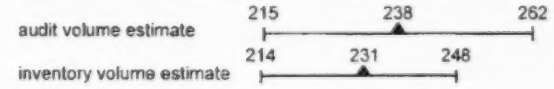
TABLE 3. Statistics for the audit volume and inventory volume estimates at 12.5+ cm dbh utilization (net decay), 1995 inventory, Invermere TSA

	Audit Volume Estimate	Inventory Volume Estimate
Number of samples	78	78
Mean (m^3/ha)	238	231
Coefficient of variation (%)	44	32
Standard error	11.8	8.5
Sampling error (%)	9.9	7.3
95% confidence Interval (m^3/ha)	215–262	214–248

Correlation coefficient r = 0.359

Ratio of means (audit/inventory volume): 1.03

Bar graph representation of 95% confidence intervals (in m^3/ha)



The correlation coefficient of 0.359 for the audit and inventory estimates indicates a moderate relationship among the individual samples. There is a 7 m^3/ha difference between the mean inventory estimate for mature volume (231 m^3/ha) and the audit estimate (238 m^3/ha). A paired-sample *t*-test determined that this difference is not statistically significant, 19 times out of 20. The 95% confidence interval for the mean paired difference is -17 to 30 m^3/ha.

Analysis of operable and inoperable volumes for 1995 inventory

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (operable areas). The audit results for the 1995 inventory were post-stratified based on this approximation. The results of the inventory audit for samples in the operable forested areas in the TSA are given in Table 4.

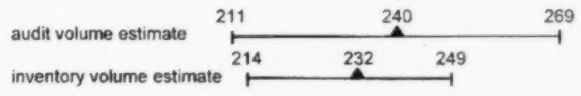
TABLE 4. Statistics for the audit volume and inventory volume estimates at 12.5+ cm dbh utilization (net decay), operable forested areas, 1995 inventory, Invermere TSA

	Operable Audit Estimate	Operable Inventory Estimate
Number of samples	57	57
Mean (m^3/ha)	240	232
Coefficient of variation (%)	46	29
Standard error	14.6	8.8
Sampling error (%)	12.2	7.6
95% confidence interval	211–269	214–249

Correlation coefficient r = 0.386

Ratio of means (audit/inventory): 1.03

Bar graph representation of 95% confidence intervals (in m^3/ha)



For the 57 samples located within the operable forested area, the mean audit volume is 240 m^3/ha and mean inventory volume is 232 m^3/ha. The difference between these two estimates (8 m^3/ha) is not statistically significant, 19 times out of 20.

For the 21 samples located in inoperable forested area, the mean audit volume was 234 m^3/ha and the corresponding inventory volume was 230 m^3/ha. The difference between these two estimates is also not statistically significant, 19 times out of 20.

Discussion and conclusions

The results of the inventory audit for the Invermere TSA suggest that the 1974 inventory of mature volume is statistically acceptable. Subsequent analysis of post-stratified data also shows a similar level of acceptability in the operable forested area. However the correlation between audit and inventory volumes in the operable area is poor. This suggested a potential lack of consistency between the audit and inventory volume estimates in the 1974 inventory.

The results of the audit for the mature component of the 1995 inventory suggest that this inventory is statistically acceptable. Subsequent analysis of post-stratified data also shows a similar level of acceptability in the operable forested area. For the 1995 inventory, the correlation between the audit and the inventory volumes is significantly improved over the 1974 inventory.

Glossary

accuracy: A measure of how close an estimate is to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building blocks around which inventory data and other information are organized for use in forest planning models, typically involving specific tree species or type groups that are further defined by site class, geographic location or similarity of management regimes.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of variation within a population, calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship, whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

dead potential trees: Standing or down dead timber which is estimated to contain at least 50% of its original gross volume in sound wood content.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground-level field procedures designed to provide physical verification of polygon inventory attributes.

free-growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees.

inoperable lands: Lands that are unsuited for timber production now and in the foreseeable future because of their topography, inaccessible location, low value of timber stands, or designation for uses incompatible with timber production.

mean: The average value of a set of observations.

polygon: A portion of land area, delineated on mid-scale aerial photographs, of "like" or uniform land cover type.

pre-inventory assessments: Inventory activities to evaluate the existing forest inventory as a basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

public sustained yield units (PSYU): A portion of a TSA; an area of Crown land, usually a natural topographic unit determined by drainage areas, managed for sustained yield by the Crown through the Ministry of Forests. It includes all Crown lands within the currently established boundaries of the unit and excludes federal lands, provincial parks, experimental forest reserves, gazetted watersheds and tree farm licences.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: The results of a statistical test comparing either two or more estimates, or an estimate to a fixed value. If the difference is too large to be attributed to chance, the difference is said to be statistically significant.

site index: An expression of the forest site quality of a stand, at a specified age, based either on the site height, or on the top height, which is a more objective measure.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: An assessment of future timber supplies over long planning horizons (more than 200 years) by using timber supply models for different scenarios identified in the planning process.

timber supply area (TSA): An area defined by an established pattern of wood flow from management units to the primary timber-using industries.

tree farm licence (TFL): Privately managed Sustained Yield Units; designed to enable owners of Crown-granted forest lands and old temporary tenures or the timber licences which replace them, to combine these with enough unencumbered Crown land to form self-contained sustained yield management units.

variable density yield prediction (VDYP) model: An empirical yield-prediction system for natural stands based on data collected in temporary inventory sample plots (TSPs) and natural, permanent growth sample plots (PSPs). VDYP predicts volume (net decay) and diameters at four utilization levels using stand height, age, and density. The aerial approach uses crown closure as the density measure.

veteran trees: Mature living trees which are remnants of an older stand.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7, 250-387-1314, fax 250-387-5999. Visit our web site at http://www.for.gov.bc.ca/resinv/homepage.htm

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